TITLE OF THE INVENTION

# FREE-STANDING CLEAR-SPAN FRAME STRUCTURE AND COMPONENTS

## BACKGROUND OF THE INVENTION

The small and medium sized building designs were developed for standard wooden based building materials. Sheet metal studs have been introduced in industrial buildings for interior and exterior walls and increasingly into residential structures to replace wood studs as the cost of wood increased. The same wood structure design was retained except, in some instances, increasing the wall stud spacing from 16 inches to from 18 and 20 inches. A building where the wooden studs have been replaced with the light sheet metal studs is described in U.S. Patent 4,688,358. This construction, except for the substitution of metal studs for wood components, uses the same design concepts and labor intensive construction methods developed for wooden structures.

In present wood constructions, metal connectors in combination with wood studs and beams are increasingly employed to reinforce the connections and to strengthen prefabricated portions such as roof truss sections for their movement from trailer bed to building. Wooden beams and sheer walls and bracings are then applied to increase strength against dead load weight stresses and lateral forces. Every wall in traditional construction depends for its integrity upon adjacent walls and connecting girts, purlins, and ridge beams. Typically, pre-assembled close-spaced walls are raised into position and held upright with temporary struts until they are secured to adjacent close-section walls. Although vertical members and the base sill are secured against lateral movement by anchor bolts and nuts, these connections and the relative weak construction of these members does not yield free-standing walls.

The traditional methods have exploited skills of trained workers, and the labor costs for constructing a building have become a major portion of the construction costs. The aging of many skilled workers and their movement to less hazardous and strenuous jobs has produced a serious skilled labor

shortage, driving up the costs of building construction. This is seriously impeding new home and small industrial building construction.

For temporary and light-weight constructions such as car ports and greenhouses, rapidly assembled light-weight frame structures have been developed as described as in U.S. Patents 5,966,890 and 6,276,111 B1, for example. While these structures are light weight and easily assembled, they lack the strength and integrity to withstand environmental stresses such as wind, and in northern climates, snow loads required for industrial and residential constructions; they are not suitable for permanent structures. Their components do not include open-space or free-standing frames.

## SUMMARY OF THE INVENTION

This invention brings to small and medium sized building construction, revolutionary new designs and methods which bring into this construction, the industrial steel materials used in large size open structures such as airplane hangers and warehouses.

This invention provides novel strong steel connectors adapted for quick assembly with steel cee-channels, HSS beams and other components to provide free-standing clear-span frame structures. With minimum bracing, these free-standing clear-span frame structures will support purlins, girts, trusses, and preassembled wall and roof components without relying on the strength of these secondary components to provide the basic integrity and strength of the frame structure.

This invention also provides an improved method of construction which enables complete framing of a small to medium-sized single or two story building with one or two minimally skilled workman and a lift or hoist operator in a single day, and that with assembled wall and roof components, enables closure and interior framing of the building in a second day by the same construction team. With suitably designed fabricated exterior wall, interior wall, floor, ceiling and roof sections, construction of the major portion of the building can be completed within the second day.

This invention also provides a scalable building design and method which provides the advances described above in buildings of all sizes.

The frames all have a base comprising two or more posts joined at the top with a joist with or without additional components. The hip frame is complete with these elements. Other frames require more. This basic construction of this invention comprises a free-standing open-span building frame comprising first and second base plates, first and second upright posts, first and second post-joist-rafter connectors, and a joist. Each base plate comprises a steel plate having an upper surface to which is welded the lower end of a steel post connector in a central portion thereof. Each steel plate has at least one anchor bolt hole therethrough on each side of the post connector. Each post has a lower end bolted to the respective steel post connector of the first and second base plate. Each post-joist-rafter connector comprises a post connector, a joist connector and a rafter connector. The first post has an upper end bolted to the post connector of the first post-joist-rafter connector, and the second post has an upper end bolted to the post connector of the second post-joist-rafter connector. The joist has first and second joist ends, the first joist end being bolted to the joist connector of the first post-joist-rafter connector, and the second joist end being bolted to the joist connector of the second post-joist-rafter connector.

The basic building frame can include a steel reinforced concrete foundation with anchor bolts extending through the base plate foundation anchor bolt holes of each base plate, each base plate being secured to the anchor bolts with nuts.

To the basic frame can be added other components such as a ridge connector and first and second rafters, the ridge connector having first and second rafter connectors; and each of the rafters having a post end and a rafter end. The post end of the first rafter can be bolted to the rafter connector of the first post-joist-rafter connector, the post end of the second rafter can be bolted to the rafter connector of the second post-joist-rafter connector, the ridge end of the first rafter can be bolted to the first rafter connector, and the ridge end of the second rafter can be connected to the second rafter connector. For a hip

roof construction, the rafter connector of each post-joist-rafter connector has a connecting surface which has a hip rafter angle.

A suitable hip roof construction includes a main frame and a hip frame adjacent thereto. The main frame includes first and second main frame post-joist-rafter connectors, first and second main frame rafters, and a ridge connector having first and second main frame rafter connectors and first and second hip rafter ridge connectors. The rafter connectors of the first and second main frame post-joist-rafter connectors each have a connecting plate aligned with the angle of its respective main frame rafter. Each of the first and second main frame rafters have a post end and a ridge end, the post end of the first rafter being bolted to the rafter connector of the first main frame post-joist-rafter connector, the post end of the second rafter being bolted to the rafter connector of the second main frame post-joist-rafter connector, the ridge end of the first rafter being bolted to the connecting plate of the first main frame rafter connector, and the ridge end of the second rafter being bolted to the connecting plate of the second main frame rafter connector. The hip frame includes first and second post-joist-hip rafter connectors and first and second hip rafters, each of the post-joist-hip rafter connectors having a post connector, a joist connector and a hip connectors. The hip rafter connectors each have a connecting plate aligned with the angle of its respective hip rafter, and said first and second hip rafter ridge connectors each having a connecting plate aligned with the angle of its respective hip rafter. The structure includes a joist having one end bolted to the joist connector of the first post-joist-hip connector and the other end bolted to the joist connector of the second post-joist-hip connector. Each of the hip rafters has a post end and a ridge end, the post end of the first hip rafter being bolted to the hip rafter connector of the first post-joist-hip rafter connector, the post end of the second hip rafter being bolted to the rafter connector of the second post-joist-hip rafter connector, the ridge end of the first hip rafter being bolted to the first hip rafter ridge connector, and the ridge end of the second hip rafter being bolted to the second hip rafter ridge connector.

The posts, joist and rafters of each frame lie in a vertical frame plane. A building frame can comprises a plurality of free-standing open-span building

frames, at least two adjacent frame planes being parallel and having a frame plane-to-frame plane distance of from 3 to 14 meters.

The building frame can include a third post construction spaced between the first and second base plates, the third post construction including a third base plate, third and fourth upright posts, a post-joist connector, and a post-rafter connector. The third base plate comprises a steel plate having an upper surface to which is welded the lower end of a steel post connector in a central portion thereof, each steel plate having at least anchor bolt hole therethrough on each side of the post connector. The post-joist connector comprises lower and upper post connectors and two joist connectors, each joist connector being bolted to a joist. The third post has a lower end bolted to the respective steel post connector of the third base plate and an upper end bolted to the lower post connector. The post rafter connector has a post connector and a rafter connector; and the fourth post having a lower end bolted to the upper post connector and an upper end bolted to a rafter connector.

The building can be stiffened and strengthened against lateral and other forces with reinforcing bars. For adjacent first and second posts in first and second adjacent frames, a first reinforcing bar can be bolted to the top of the first post and to the bottom of the second post, and a second reinforcing bar can be bolted to the top of the second post and to the bottom of the first post. This construction can be repeated symmetrically throughout the building for buildings exposed to severe conditions.

In preparation for completion of the building, girts can be secured to adjacent posts by self-tapping screws, and purlins can be secured to adjacent rafters by self-tapping screws.

The roof construction can use first and second steel clips, each having a rafter connector and a ridge purlin connector forming a 90° angle therebetween with a first steel clip rafter connector attached to each of two adjacent rafters and a second steel clip rafter connector attached to other of the two adjacent rafters. A ridge purlin connector can extend between and attached to the ridge purlin connectors of the first and second clips.

The individual connectors used in the building frame are a part of this invention.

The invention includes a base plate comprising a steel plate having an upper surface and a steel post connector having a rectilinear cross-section and a lower end, the lower end of the post connector being welded to a central portion of the upper surface with at least one anchor bolt hole therethrough on each side of the post connector. The post can be channel or HSS with a rectangular cross-section.

The steel post-joist-rafter connector of this invention comprises a post channel with an upper end and a lower end, and a joist channel having a first end and a second end. The post channel comprises a web and first and second parallel post channel flanges, and a joist channel comprises a web and first and second parallel joist channel flanges. The flanges and web of the first end of the joist channel are welded to an outer surface of a post channel flange and the flanges and web of the upper end of the post channel are welded to a rafter connector plate positioned at a lower rafter surface angle. The webs of the post channel and the joist channel being in approximately the same plane, and the flanges of the post channel and the joist channel extend in the same direction from their respective webs. Sets of bolt holes in the webs are adjacent to the lower end of the post channel and adjacent to the second end of the joist channel. In one embodiment, at least one reinforcing plate is welded to the web and flanges of the post channel in alignment with a flange of the joist channel. For post-joist-rafter connectors wherein the rafter is a hip rafter, the rafter plate is positioned at a hip rafter plate angle.

The ridge connector of this invention comprises first and second rafter channels, each rafter channel having a web and first and second parallel flanges. The first rafter channel has first and second ends, and the second rafter channel having third and fourth ends. The first end web and flanges of the first rafter channel are welded to the third end web and flanges of the second rafter channel, the webs forming a roof peak angle. The second and fourth ends of the channels each have a set of bolt holes for securing rafters to the connector. When assembled, each of the rafter channels is mated with the

end of a rafter cee-channel and bolted thereto, the outer dimensions of the rafter channel and the inner dimensions of the cee-channel being selected to form a snug fit, which can optionally have maximum surface to surface distances of less than 2 mm.

The splice connector of this invention comprises first and second channels, the first channel having a first and second end and the second channel having a third and fourth end. The first end web and flanges of the first splice channel are aligned with and welded to the third end web and flanges of the second splice channel. The second and fourth ends of the splice channels each have a set of bolt holes for securing cee-channel to the connector. When assembled, each of the splice channels is mated with the end of a cee-channel and bolted thereto, the outer dimensions of the channels and the inner dimensions of the cee-channels being selected to form a snug fit with maximum surface to surface distances of less than 2 mm.

The ridge butt connector of this invention comprises a first main rafter channel having a first and second end, a second main rafter channel having a third and fourth end, a first hip channel having a fifth and sixth end, and a second hip channel having a seventh and eighth end. The first end web and flanges of the first main rafter channel are welded to the third end web and flanges of the second main rafter channel, the main channel webs forming a roof peak angle. The fifth end web and flanges of the third hip rafter channel are welded to the seventh end web and flanges of the fourth hip channel and the fifth and seventh ends are welded the inner surfaces of the first and third end web and flanges, the upper flanges of the third and fourth hip channels forming a hip peak angle with the webs of the first and second main rafter channels. A set of bolt holes are provided adjacent the second, fourth, sixth and eighth ends for securing rafters to the channels.

The slope change connector comprises a main rafter channel having a web and parallel flanges, and a slope changed rafter channel having a web and parallel flanges. An end of the web and flanges of the main rafter channel are welded to an end of web and flanges of the slope changed rafter channel. The webs of the main rafter channel and the slope changed rafter channel each

have a set of bolt holes, and the webs of the main rafter channel and the slope changed rafter channel have a common plane.

The slope-butt connector of this invention comprises a slope rafter connector channel with a web and parallel flanges, and a post connector channel having upper and lower ends and first and second parallel post connector channel flanges. One end of the flanges and web of the slope rafter connector are welded to the first post connector channel flange, the angle between the flanges of the slope rafter connector and the first post connector channel flanges constituting the slope angle.

The T-connector of this invention comprises a post channel having a web and first and second parallel post channel flanges and a joist channel with a web and first and second parallel joist channel flanges. The webs of the post channel and the joist channel are in the same plane, and each of the flanges forming a 90° angle with its respective web. Both ends of the post channel have at least one set of post bolt holes for securing the post channel to posts. The joist channel has first and second ends, the first end having at least one set of joist bolt holes for securing the joist channel to a joist. The flanges and web of the second end of the joist channel are welded to a flange of the post channel between the sets of post bolt holes. In one embodiment, at least one reinforcing plate is welded to the web and flanges of the post channel in alignment with a flange of the joist channel.

The X-connector of this invention comprises a post channel having a web and first and second parallel post channel flanges, and first and second joist channels having a web and first and second parallel joist channel flanges. The webs of the post channel and the joist channels are in the same plane. Each of the flanges forms a 90° angle with its respective web, and both ends of the post channel having at least one set of post bolt holes for securing the post channel to posts. The first joist channel has first and second ends, and the second joist channel has third and fourth ends. The first and third ends each have at least one set of joist bolt holes for securing the respective joist channel to a joist. The flanges and web of the second end of the joist channel are welded to the first flange of the post channel between the post bolt holes, and

the flanges and web of the fourth end of the joist channel are welded to the second flange of the post channel in alignment with the flanges of first joist channel.

The post-rafter connector of this invention a post channel having a web and first and second parallel post channel flanges, and having an upper end and a lower end with a set of bolt holes for securing the post channel to a post. A rafter connector has a web and upper and lower flanges and has a first and second end, each of the flanges forming a 90°angle with its respective web. The first and second ends each have a set of bolt holes for bolting the rafter connector to the ends of rafters, the ends of the web and flanges of the upper end of the post channel being welded to the lower flange of the rafter connector to form with the rafter channel flange an angle which maintains the slope of the upper flange at a roof slope angle. In one embodiment, at least one reinforcing plate is welded to the web and flanges of the post channel adjacent to the upper end thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of a free-standing clear-span frame structure of this invention.

Fig. 2 is a schematic view of the free-standing clear-span frame structure of Fig. 1 with added ridge beam, hip beams, and cross-bars.

Fig.3 is a schematic view of a free-standing clear-span frame structure according to this invention supporting purlins and girts.

Fig. 4 is a top cross-sectional view of channel post base of this invention.

Fig. 5 is a cross-sectional view of the channel post base of Fig. 4 taken along the Line 5—5.

Fig. 6 is a top cross-sectional view of a HSS post base of this invention.

Fig. 7 is a cross-sectional view of the HSS post base of Fig. 6 taken along the line 7—7.

Fig. 8 is a front view of a post-joist-rafter connector of this invention

Fig. 9 is a rear view of the post-joist-rafter connector of Fig. 8.

Fig. 10 is a top view of a ridge connector according to this invention.

Fig. 11 is a cross-sectional view of the ridge connector of Fig. 10 taken along the line 11—11.

Fig. 12 is a cross-sectional view of the ridge connector of Fig. 10 taken along the line 12—12.

Fig. 13 is a top view of a splice connector according to this invention.

Fig. 14 is a cross-sectional view of the splice connector of Fig. 13 taken along the line 14—14.

Fig. 15 is a cross-sectional view of the splice connector of Fig. 14 taken along the line 15—15.

Fig. 16 is a top view of a ridge-butt connector according to this invention.

Fig. 17 is a front view of the ridge-butt connector of Fig. 17.

Fig. 18 is a back view of the ridge-butt connector of Figs. 16 and 17.

Fig. 19 is a top view of a hip frame according to this invention.

Fig. 20 is a front view of the hip frame of Fig. 19.

Fig. 21 is a bottom view of a rafter plate to hip rafter connection of the hip frames of Figs. 19 and 20.

Fig. 22 is a view of a clip according to this invention.

Fig. 23 is a side view of the clip of Fig. 22.

Fig. 24 is a cross-sectional view of the clip of Fig. 22 taken along the line 24—24.

Fig. 25 is a front view of a ridge purlin centrally supported on a ridge connector with a clip of Fig. 22 according to this invention.

Fig. 26 is a front view of two purlins supported off the center of a ridge connector with purlin clips of Fig. 22.

Fig. 27 is a front view of a purlin and clip secured to the web portion on a cee-channel with a clip of Fig. 22.

Fig. 28 is a cross-sectional view of the purlin secured to the web portion of Fig. 27, taken along the line 28—28.

Fig. 29 is a front view of a slope butt connector according to this invention.

Fig. 30 is a front view of the slope-butt connector of Fig. 29 bolted to upper and lower posts and a slope rafter.

Fig. 31 is a front view of a slope change connector.

Fig. 32 is a front view of the slope change connector of Fig. 31 secured to a main rafter and a lower slope changed rafter.

Fig. 33 is a front view of a T-connector according to this invention.

Fig. 34 is an end view of the T-connector of Fig. 33.

Fig. 35 is a front view of an X-connector according to this invention.

Fig. 36 is a bottom view of the X-connector of Fig. 35.

Fig. 37 is a front view of a center post embodiment of this invention including a post to rafter connector shown connected to a cee-channel post and rafter, in combination with a joist to X-connector, shown connected to cee-channel posts, joists and rafter.

Fig. 38 is a front view of the post-rafter connector of Fig. 37 without post and rafter.

Fig. 39 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 39—39.

Fig. 40 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 40—40.

Fig. 41 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 41—41.

DETAILED DESCRIPTION OF THE INVENTION

The objectives, structures and methods of this invention are described in greater detail in the drawings and following descriptions.

The term “post” as used in this application is defined as a vertical member for supporting the structure.

The term “joist” as used in this application is defined as a horizontal ceiling support.

The term “rafter” as used in this application is defined to be a primary roof support member.

The term “purlin” as used in this application is defined to be a secondary horizontal roof support member.

The term “girt” as used in this application is defined to be a secondary horizontal wall support member.

The term “snug fit” is used in this application to describe the space between the opposed surfaces of the connectors of this invention and the cee-channels, round pipes or HSS beams bolted thereto. A snug fit is defined to denote a maximum contact surface to opposed contact surface distance of not more than 2 mm.

The term “channel” as used in this application is defined as a three-sided piece of metal comprising a web and first and second parallel flanges, each of the flanges forming a 90° angle with respect to the web.

Only one member or each mirrored pair of connectors of this invention are set forth in the following descriptions. Mirrored counterparts of these structures have the same but mirrored construction and are also to be considered within the scope of this invention.

The connectors of this invention with the exception of Figs. 5 and 6 are shown bolted to cee-channels. For stronger structures, the cee-channels may be replaced with stronger HSS sections or pipe having round cross-sections, and in that event, the channel connectors will be replaced with corresponding matching connectors constructed in a manner which will be readily apparent to a person skilled in the art. Both the cee-channel and these alternative structured connectors are intended to be included within the scope of this invention.

Fig. 1 is a schematic view of a free-standing clear-span frame structure of this invention.

The term "free-standing" is used herein to indicate frames that are strongly secured to a foundation against lateral, vertical and torque forces and entirely support the vertical dead weight associated with building components they support without the assistance of secondary building components. With the assistance of cross-bars, these frames entirely supports the building

components against lateral stresses of wind and earthquake, and the torque forces generated by these lateral forces.

The term "clear-span" is used herein to identify the novel approach to small and medium sized building construction made possible by this invention, where the weight and stress bearing skeletal components of the building are assembled in spaced free-standing upright frames in the first stage of the construction. Spacing between adjacent free-standing frames is limited only by the needs of the secondary components to be supported on the frames. Larger spacing is entirely optional if stronger girts, purlins, and trusses are used to span the distances.

The free-standing frames are completely assembled without the need for on-site welding. The components are entirely assembled using novel connectors, and conventional bolts and nuts. The frame is secured to the foundation using novel post plates, and anchor bolts and nuts.

Heavy self-tapping screws are used to attach the girts, purlins, trusses, and other components needed to support walls, floors, ceilings and roof components to these free-standing clear-span frames. This structure and method enables increased use of preassembled components such as reinforced roofs, exterior walls, and interior walls in the form of completely self-contained panels that can be secured directly to the frame members with heavy self-tapping screws.

Fig. 1 shows a series of free-standing, single story open span frames 2, 4, 5 and 6. Hip frame 2 comprises channel posts 8 and 10 with their lower ends secured to the foundations 12 and 14 by post base plate connectors 18, details of which are described with respect to Figs. 4 and 5 hereinafter. The upper ends of the posts 8 and 10 are connected to a joist 20 by post-joist connectors 22 and its mirrored structure 23, details of which are described hereinafter with respect to Figs.19-21.

Frames 4, 5 and 6 are substantially identical. Frame 4 comprises a pair of posts 24 and 26, their lower ends secured to respective foundations 12 and 14 by post base plate connectors 18, and their upper ends connected to joist 28 and rafters 30 and 32 by post-joist-rafter connectors 34 and their mirrored

counterpart connectors 35, details of which are described with respect to Figs. 8 and 9 hereinafter. The upper ends of the rafters 30 and 32 are joined together by hip roof ridge connector 33, details of which are described with respect to Figs. 16 -18 hereinafter.

Frame 5 comprises a pair of posts 36 and 38, their lower ends being secured to respective foundations 12 and 14 by post base plate connectors 18, their upper ends being connected to joist 40 and rafters 42 and 44 by post-joist-rafter connectors 34. The upper ends of the rafters 42 and 44 are joined by roof ridge connectors 37, details of which are described with respect to Figs. 10-12, 25 and 26 hereinafter.

The spacing between posts 8 and 24, between posts 24 and 36 will depend upon the building design selected. Distances of 3 to 14 meters are entirely within the capabilities of this design. The distance between hip roof posts 8 and adjacent frame post 24 are selected based on the dimensions of the hip component. The distances between the posts of each frame and between adjacent frames are selected from design considerations which take into consideration the overall size of the building, and the economies in costs and labor realized balancing the labor savings derived from use of fewer, more widely spaced frames, and the costs of stronger secondary structures required to span larger distances. In locations and circumstances where speed of construction and labor costs are the most dominant factors, larger spacings are advantageous. Figs 1 and 2 show a hip frame and three standard single-story frames. The number of frames, the post spacings, and the frame-to-frame spacings are relatively unlimited as will be readily apparent to a person skilled in the art, and all numbers and variations in free-standing open-span frame constructions are intended to be included with the scope of this invention.

The posts, joists and rafters used in the frames of Fig. 1 are standard construction components used in the industrial building industry. Based on the strength needs for a particular building, they can be steel channels, cee-channels, HSS beams, Z-beams, I-beams, round beams, or other conventional heavy structural beams having the requisite strength to span the distances between the posts and to carry the weights and meet the stress specifications

of the building. For taller buildings and for larger post spacings, beams having a larger size and/or wall thickness are used. The beam strengths and thus the corresponding choice of size and thickness required to meet the code and design specifications for a building are part of the design parameters of buildings, and their selection is fully within the skill of a person skilled in the art of building design.

Fig. 2 is a schematic view of the free-standing clear-span frame structure of Fig. 1 with added secondary structures, ridge beams, hip rafters, and lateral stress cross-bars. The lower end of the secondary component hip rafters 46 and 48 connect with the post-joist-rafter connectors 22 and 23 at the upper ends of posts 8 and 10, and their upper ends come together to connect with the hip roof ridge connector 33. The hip rafters 46 and 48 support sloped roof components of the hip roof construction.

Another secondary component is a ridge purlin 50 which connects the hip roof ridge connector 33 with the roof ridge connector 37. The ridge purlin 50 supports the roof components.

To increase the stiffness of the frames and their resistance to lateral stresses caused by high winds and earthquakes, cross-bars 52 and 54 can be used to connect the tops and bottoms of posts 24 and 36, i.e., cross-bar 54 connecting the top of post 24 to bottom of post 36, and cross-bar 52 connecting the top of post 36 to bottom of post 24. Matching cross-bars connect the tops and bottoms of posts 26 and 38 on the opposite side of the structure. Cross-bars can also be used to connect roof peaks of one frame to posts of an adjacent frame to increase roof stiffness. Movement of a frame with a vector in either direction normal to the plane of the fame is resisted by tensile strength of at least one of the reinforcing rods with this cross-bracing design.

Fig.3 is a schematic view of a free-standing clear-span frame structure of this invention with the purlins and girts attached thereto. In this configuration, the building comprises four free-standing clear-span frames 60, 62, 64 and 66, constructed as described hereinabove with respect to Fig. 1. The front frame 60 has posts 68 and 70. Rafters 72 and 74 and horizontal joists 76 and 78 are attached to the posts 68 and 70 by post-joist-rafter

connectors 34 and 35. Secondary studs together with the posts 68 and 70 support horizontal girts, door lintels and jambs, window sills, lintels and jambs, and horizontal girts are secured to the rafters 72 and 74. Additional girts and purlins also extend between posts of end frame 66, and between the opposing posts of adjacent frames to provide support for external and interior walls, doors, and windows, and the roof components.

Fig. 4 is a top cross-sectional view of channel post base of this invention, and Fig. 5 is a cross-sectional view of the channel post base of Fig. 4 taken along the Line 5—5. The base plate 80 has a rectangular shape with longer sides 82 and shorter sides 84. A section of channel 86 is welded perpendicular to the base plate 80 in the central portion thereof, the channel web 88 oriented parallel to the shorter sides 84 and the channel flanges 90 oriented parallel to the longer sides 82. Anchor bolts embedded in the steel reinforced foundation 91 extend through matched holes (not shown) in the base plate 80, the holes being aligned with the anchor bolts. The base plate is secured to the anchor bolts with nuts 92. A cee-channel post 94 is secured to the channel 86 by standard heavy bolts and nuts (now shown).

The external web dimension of the channel 86 closely matches the internal web dimension of the cee-channel so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 6 is a top cross-sectional view of HSS post base of this invention, and Fig. 7 is a cross-sectional view of the channel post base of Fig. 6 taken along the Line 7—7. The base plate 96 has a rectangular shape with longer sides 98 and shorter sides 100. A section of HSS 102 is welded perpendicular to the base plate 96 in the central portion thereof, the four sides of the HSS being oriented parallel to the respective longer sides 98 and shorter sides 100. Anchor bolts embedded in the steel reinforced foundation 101 extend through matched holes in the base plate 96 (not shown). The base plate 96 is secured to the anchor bolts by nuts 103. A HSS post 104 is secured to the HSS section 102.

The external dimensions of the channel HSS section 102 closely match the internal dimensions of the HSS post 104 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 8 is a front view of the post-joist-rafter connector 109 of this invention shown as 34 in Figs. 1-3, and Fig. 9 is a rear view of the post-joist-rafter connector of Fig. 8. Post-joist-rafter connector 109 shows the basic construction of the post-joist-rafter connector 34 in Figs. 1 and 2. The terminal end of a post channel connector 110 having a post channel web 112 and first and second post channel flanges 114 and 116 is welded to rafter connector plate 118 having an angle matching the slope desired for the rafter 120. A joist channel connector 122 has joist channel web 124 and joist channel flange portions 126 and 128, one end of which are welded perpendicular to the first flange 114 of the post channel connector 110. Post reinforcing plates 130 and 132 are welded to the web 112 and opposed flanges 114 and 116 in alignment with the flanges 126 and 128 of the joist connector 122.

A post cee-channel 131 is secured to the post channel connector 110 by strong bolts and nuts (not shown), the external dimensions of the web 112 being a close match for the internal web dimensions of the cee-channel web 134 to form a secure bolt and nut connection. A joist cee-channel 136 is secured to the joist channel connector 122 by strong bolts and nuts (not shown), the external dimensions of the web 124 being a close match for the internal web dimensions of the joist cee-channel web 138 to form a secure bolt and nut connection.

The lower flange 140 of the cee-channel rafter 120 is secured to the rafter connector plate 118 by bolts and nuts (not shown).

The webs 112 and 124 each have a set of bolt holes 125 for attaching the connectors to their respective cee-channels.

The external dimensions of the connectors closely match the internal dimensions of the cee-channel connected thereto so that when bolted together, they form a snug fit, yielding a strong secure union.

Referring to Figs. 1-3, a mirrored counterpart 35 of the post-joist-rafter connector 34 is used for connecting the post, joist and rafters of the opposite

side of the frame. Alternative arrangements of flanges and webs shown in Fig. 9 which achieve the same overall configuration will be readily apparent to a person skilled in the art, and these alternative configurations are considered to be fully within the scope of this invention.

Fig. 10 is a top view of a ridge connector according to this invention. Fig. 11 is a cross-sectional view of the ridge connector of Fig. 10 taken along the line 11—11, and Fig. 12 is a cross-sectional view of the ridge connector of Fig. 10 taken along the line 12—12.

Referring to Fig. 12, the ridge connector connector 150 is formed from two channel connectors 152 and 154, their ends welded together to form an angle "a" which corresponds to the angle of the peak of the roof. Rafter cee-channels 156 and 158 are secured to the respective rafter connectors 152 and 154 with strong bolts and nuts 155. The external width dimensions of the rafter connectors 152 and 154 correspond closely with the internal web dimensions of the rafter cee-channels 156 and 158 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 13 is a top view of a splice connector according to this invention. Fig. 14 is a cross-sectional view of the splice connector connector of Fig. 13 taken along the line 14—14, and Fig. 15 is a cross-sectional view of the splice connector connector of Fig. 14 taken along the line 15—15. Referring to Fig. 15, the splice connector connector is a section of channel 160 to which two sections of cee-channel 162 and 164 are attached by strong bolts and nuts 165. The external width dimensions of the channel 160 correspond closely with the internal web dimensions of the cee-channels 162 and 164 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 16 is a top view of a ridge-butt connector according to this invention, Fig. 17 is a front view of the ridge-butt connector of Fig. 16, and Fig. 18 is a back view of the ridge-butt connector of Figs. 16 and 17. The connector169 is made of four sections of channel, two connector sections 170 and 172 constituting roof rafter connectors. One end of each rafter connector is welded to the other to form an angle "**b**" shown in Fig. 18. Angle "**b**" corresponds to the angle formed by the peak of the roof. Hip rafter connectors 174 and 176

converge together, and their converged ends are welded to the central portion of the rafter connectors 170 and 172. The hip rafter connectors are welded to form the angles and orientation of the respective hip rafters. Because of the complexity of the ridge-butt connector connector, it is shown without the roof and hip rafters connected by the ridge-butt connector connectors. When installed, cee-channel roof rafters (not shown) are secured to the rafter connectors 170 and 172 (as shown in Figs. 10-12) described hereinabove with strong bolts and nuts through the bolt holes 171 shown at the end of each connector. Cee-channel hip rafters are similarly secured to the hip rafter connectors 174 and 176 with strong bolts and nuts.

These cee-channel rafters are attached to the corresponding respective connectors by strong bolts and nuts (not shown), and the external width dimensions of the channel connectors are selected to correspond closely with the internal web dimensions of the respective cee-channel rafters to form strong rigid connections.

Fig. 19 is a top view of a hip frame 181 according to this invention, and Fig. 20 is a front view of the hip frame of Fig. 19. Fig. 21 is a bottom view of a rafter plate to hip rafter connection of Figs. 19 and 20. Main roof rafters 180 and 182 are bolted to the connectors 170 and 172 of ridge-butt connector 169 shown in Figs. 16-18. The upper ends 184 and 186 of respective hip rafters 188 and 190 are bolted to the respective connectors 174 and 176 of the ridge-butt connector shown in Figs. 16-18. Lower flange sections 192 and 194 of the hip rafters 188 and 190 are bolted to connector plates 196 and 198 of the hip frame 181.

The difference between the post-joist-roof rafter connector of Figs. 8 and 9 and the post-joist-hip rafter of Figs. 19-21 is the hip rafter connecting (upper) surfaces of the connector plates 196 and 198; these surfaces are oriented in the plane of the lowermost flanges 192 and 194 of the hip rafter cee-channels 188 and 190. Bolt holes 200 are placed to effect a secure bolt connection between the plates and the respective hip rafters. The external dimensions of the connectors closely match the internal dimensions of the cee-channel

connected thereto so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 22 is a view of a clip according to this invention, Fig. 23 is a side view of the clip of Fig. 22, and Fig. 24 is a cross-sectional view of the clip of Fig. 22 taken along line 24—24. The clip is formed from two L-channel flanges 220 and 222 which form an angle "**c**" of 90°. The end of one L-channel flange 220 has at least two holes 226 (four holes are shown), for securing corresponding cee-channel sections thereto by bolts or heavy self-tapping screws. The opposite end of the other L-channel flange 222 has at least two holes 224 (four holes are shown), for securing corresponding cee-channel sections thereto by screws.

Fig. 25 is a front view of a purlin supported centrally on a ridge connector with a clip of Figs. 22-24 according to this invention. The flange 220 of the clip is secured to cee-channel 228 of the converging cee-channels 228 and 230 of roof rafters, these roof rafters as shown in Figs. 10-12 are secured to a roof rafter connector by bolts or self-tapping screws 232. A centrally located roof peak purlin 234 is secured to flange 222 by bolts or self-drilling screws 236 which extend through the holes 224 (Fig. 22) into the purlin 234.

Fig. 26 is a front view of two purlins supported off the center of a ridge connector with purlin clips of Fig. 22. Two rafters 240 and 242 are secured to a rafter connector 244 (shown in Figs. 10-12) by bolts or self-tapping screws (not shown). Clip 248 is secured to rafter 240 by bolts or self-drilling screws 252 extending through corresponding holes in the clip flange (shown in Figs. 22-24). Another clip 250 having an opposite hole configuration (forming a mirrored duplicate) of clip 248 is secured to rafter 242 by bolts or self-drilling screws 252 extending through corresponding holes in the respective flanges. Roof purlins 254 and 256 are secured to the respective clips 248 and 250 by bolts or self-drilling screws 258 extending through corresponding holes (shown in Figs. 22-24) in the clip flanges. The clips 248 and 250 are positioned off the center of the rafter connector 244 and at an angle perpendicular to the angle of the respective rafters as required by this roof peak construction. It will be readily apparent to a person skilled in the art that the orientation of the clips can be

reversed and the angles selected for the clips can be varied, and these variations are considered to be fully within the scope of this invention.

Fig. 27 is a front view of a purlin secured to the web portion on a cee-channel with a clip of Fig. 22, and Fig. 28 is a cross-sectional view of the purlin secured to the web portion of Fig. 27, taken along the line 28—28.

Flange portion 259 of the clip 260 is attached normal to a cee-channel 262 by bolts or self-tapping screws 264. A purlin 266 is secured to the other flange portion 268 of the clip 260 by bolts or self-tapping screws 270. It will be readily apparent to a person skilled in the art that the orientation of the clip can be reversed and the angle selected for the clip can be varied to fit the design constraints of the building, and these variations are considered to be fully within the scope of this invention.

Fig. 29 is a front view of a slope-butt connector according to this invention, and Fig. 30 is a front view of the slope-butt connector of Fig. 29 bolted to upper and lower posts and a slope rafter.

The slope-butt connector is useful for connecting lower and upper posts with each other and connecting to a sloped rafter. The slope-butt connector 300 is formed with a slope rafter connector channel section 301 with flanges 302 and 303 and web 304. The ends 305 and 306 of respective flanges 302 and 303, and the end 307 of web 304 are welded at a slope angle "**d**" to the flange 308 of post channel section 309. The ends of reinforcing plates 310 and 311 are welded to the flanges 308 and 312 and one side of the reinforcing plates 310 and 311 are welded to web 313 of channel section 309 in alignment with the flange ends 305 and 306 of the channel section 301. The ends of web 313 each have sets of holes 314 and 315, and the web 304 has as set of holes through which bolts can be extended to secure the cee-channel posts and rafter to the slope-butt connector.

Referring to Fig. 30, rafter cee-channel 316 is bolted to the slope rafter connector 301 through holes 315 (Fig. 29) with bolts 319, and the post sections 317 and 318 are bolted to the post connector 309 through holes 314 (Fig. 29) with bolts and nuts 321. The external width dimensions of the post connector 309 and the rafter connectors 301 correspond closely with the internal

dimensions of the respective post cee-channels 317 and 318 and the rafter cee-channel 316 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 31 is a front view of a slope change connector, and Fig. 32 is a front view of the slope change connector of Fig. 31 secured to a main rafter and a lower slope changed rafter. The slope change connector 600 is formed from two rafter channel connectors 601 and 602. The ends of the flanges 604 and 606 and the web 608 of one end of channel connector 601 are welded to the respective ends of the flanges 610 and 612 and the web 614 of channel connector 602 to form an angle "e" which corresponds to the angle of the slope change. The ends of webs 608 and 614 have sets of holes 616 and 618 for securing rafter channels to the connectors.

Referring to Fig. 32, rafter cee-channels 620 and 622 are secured to the respective rafter connectors 601 and 602 by strong bolts and nuts 624. The external dimensions of the rafter connectors 601 and 602 correspond closely with the internal dimensions of the rafter cee-channels 620 and 622 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 33 is a front view of a T-connector according to this invention, and Fig. 34 is an end view of the T-connector of Fig. 33. The T-connector is useful for connecting lower and upper end posts of a two-story structure with each other and with a horizontal joist. The T-connector 339 is formed with a channel section 340 with flanges 342 and 344 and web 346. The ends 347 and 349 of respective flanges 348 and 350 , and the end 351 of web 352 of channel section 353 are welded at right angles to the flange 342 of channel section 340. Reinforcing plates 354 and 356 are welded to the flanges 342 and 344 and web 346 of channel section 340 in alignment with the flanges 348 and 350 of the channel section 353. The ends of web 346 have sets of holes 358 and 360, and the end of web 352 has as set of holes 359 through which strong bolts and nuts can be extended to secure connecting cee-channel joists to the T-connector.

Fig. 35 is a front view of an X-connector according to this invention, and Fig. 36 is a bottom view of the X-connector of Fig. 35. The X-connector is

useful for connecting upper and lower intermediate posts to each other and to horizontal joists. The X-connector 370 is formed with a channel section 372 with flanges 374 and 376 and web 378. The two wings of the X configuration are formed by channel sections 380 and 382. The ends 384 and 386 of respective flanges 388 and 390, and the end 392 of web 396 of channel section 388 are welded at right angles to the flange 374 of channel section 372. The ends 400 and 402 of respective flanges 404 and 406, and the end 408 of web 410 of channel section 382 are welded at right angles to the flange 376 of channel section 372.

Reinforcing plate 414 is welded to the flanges 374 and 376, and to web 378 of channel section 372 in alignment with flanges 388 and 404 of the respective channel sections 380 and 382. Reinforcing plate 416 is welded to the flanges 374 and 376, and to web 378 of channel section 372 in alignment with flanges 390 and 406 of the respective channel sections 380 and 382.

Each end of web 378 have sets of holes 416 and 418, and the ends of both webs 396 and 410 have sets of holes 420 and 422 through which strong bolts and nuts can be extended to secure connecting cee-channel or joists to the wings of the X-connector.

Fig. 37 is a front view of an intermediate post embodiment of this invention including a post to rafter connector shown connected to a cee-channel post and rafter, in combination with a joist to X-connector, shown connected to cee-channel posts, joists and rafter. Fig. 38 is a front view of the post-rafter connector of Fig. 37 without post and rafter.

The connectors shown in Figs. 37and 38 are useful for posts positioned between the side posts of a frame because the distance between the joists and rafter for the center posts requires an additional post segment and two rafter segments. The lower and upper posts are joined by the X-connector, and the top of the upper post is connected to a rafter by the post-rafter connector. Details of the X-connector are described with respect to Figs. 35 and 36.

Referring to Fig. 38, the post and rafter connector 500 is formed by welding a post connector channel 502 to a flange 503 of rafter connector channel 504, the end 506 of the post connector channel 502 being cut at an

angle **"f"** corresponding to the slope of the roof. The rafter channel 504 welded thereto is thus angled at the slope of the roof. Reinforcing plate 508 is welded to the flanges 510 and 512 and web 513 of the post channel 502 at right angles to the respective flanges and web. Reinforcing plates 514 and 516 are welded to the flanges 503 and 518 and web 520 of the rafter channel 504 at right angles to the respective flanges and web. Bolt holes 522 are positioned near the ends of the webs 513 and 520.

Referring to Fig. 37, the cee-channel posts 525 and 527are bolted by bolts and nuts 524 to the top and bottom of web 378 of the X-connector 370 shown in detail in Figs. 35-36. Cee-channel joists 526 and 528 are secured by bolts and nuts 524 to the joist connector webs 396 and 410 of the X-connector.

The rafter segments 530 and 532 are secured by bolts 524 to the ends of web 520 of the rafter channel 504 of the post-rafter connector 500. The web 513 is secured by bolts 524 to the upper end of post 525.

Fig. 39 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 39—39. The outer dimensions of the channel flanges 518 and 503, and of the web 520 correspond closely with the inner dimensions of the cee-channel 532 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 40 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 40—40. The outer dimensions of the channel flanges 388 and 390 and web 396 (Fig. 35) correspond closely with the inner dimensions of the cee-channel 526 so that when bolted together, they form a snug fit, yielding a strong secure union.

Fig. 41 is a cross-sectional view of the post-rafter connector of Fig. 37 taken along the line 41—41. The outer dimensions of the channel flanges 376 and 374 and web 412 (Fig. 35) correspond closely with the inner dimensions of the cee-channel 527 so that when bolted together, they form a snug fit, yielding a strong secure union.